Fishery Data Series No. 05-26

Smolt Production, Adult Harvest, and Spawning Escapement of Coho Salmon from Nakwasina River in Southeast Alaska, 2002-2003

by

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May 2005

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Department of Fish and Game	ADF&G
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA REPORT NO. 05-26

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ABSTRACT

In 1998, a coded wire tag (CWT) project was began for coho salmon in Nakwasina River near Sitka, Alaska, to supplement a continuing regionwide effort to assess the status of key coho salmon *Oncorhynchus kisutch* stocks in Southeast Alaska. Two-thousand three was the sixth season of a continuing project in which smolt abundance, adult harvest, and escapement were estimated. During spring 2002, 5,686 coho salmon smolt ≥70-mm fork length (FL) were captured in minnow traps, marked with an adipose fin clip, given a CWT, and released. Smolt abundance in 2002 was an estimated 22,472 (SE = 1,660). During fall 2003, 46 (of 773,556 sampled) adult coho salmon bearing CWTs with a Nakwasina River code were recovered in random sampling of marine fisheries, and 22.5% of 901 adults examined inriver carried CWTs, as evidenced by adipose fin clips. An estimated 604 (SE = 109) coho salmon of Nakwasina River origin were harvested in Southeast Alaska marine fisheries in 2003. The marine sport fishery harvested an estimated 114 fish, or 19% of the total harvest of Nakwasina River coho salmon, while the commercial troll fishery contributed the remaining 81%.

An open-population mark-recapture experiment was also conducted to estimate the abundance of coho salmon in Nakwasina River during fall 2003. An estimated 2,063 (SE=233) adults escaped into Nakwasina River. This represents a factor of 4.8 times greater than the peak visual count of 439 adult coho salmon observed during foot surveys of the main river in 2003. The total run (i.e., escapement plus harvest) for all coho salmon bound for Nakwasina River was 2,667, the marine survival rate was 11.9%, and the marine fishery exploitation was 22.6%.

Key words: coho salmon, *Oncorhynchus kisutch*, Nakwasina River, harvest, troll fishery, sport fishery, migratory timing, return, exploitation rate, marine survival, coded wire tag, mark-recapture experiment, spawning escapement, smolt abundance, Southeast Alaska.

INTRODUCTION

Coho salmon *Oncorhynchus kisutch* produced by Nakwasina River and thousands of other coastal river systems in Southeast Alaska collectively support the region's mixed stock commercial troll and net fisheries and freshwater and marine sport fisheries. The Alaska Department of Fish and Game (ADF&G) has conducted comprehensive coded wire tag (CWT) assessment projects on a long-term basis to evaluate the effects of Southeast Alaska fisheries on specific coho stocks native to streams in northern and inside areas of Southeast Alaska (Yanusz et al. 1999), but stock-specific information is more limited for outside, central, and southern areas. To bridge geographic areas, projects have been implemented more recently for specific stocks, including the Unuk River in southern Southeast (Jones III et al. 1999, 2001; Weller et al. 2002; 2003) and Slippery Creek in central Southeast (Beers 1999). Along the outer coast, the first comprehensive CWT program began at Ford Arm in 1982 and has continued through 2003 (Shaul and Crabtree 1998; Leon Shaul, Personal Communication, Alaska Department of Fish and Game, Commercial Fisheries Division, Douglas). In southern Southeast, Chuck Creek has been included as a coho stock assessment project. The Division of Sport Fish also conducted a CWT project to assess fishery impacts to Salmon Lake (near Sitka) coho salmon from 1983 to 1990 and again in 1994-1995 (Schmidt 1996). The Salmon Lake CWT project was initiated again in 2001 with adult returns expected through 2005.

Beginning in 1998 and continuing through 2003, the Sport Fish Division conducted a CWT project for coho salmon in Nakwasina River (Figure 1) to supplement the regionwide effort to assess the status of key coho salmon stocks in central Southeast Alaska (Brookover et al. 1999; 2000; 2003; Tydingco 2003). Estimated smolt abundance from 1998 through 2001 ranged between 102,794 (SE = 15,255) in 1998 and 47,571 (SE = 6,402) in 1999. Estimated harvests of returning adults in 1999 - 2002 ranged from 1,983 (SE=605) in 1999 to 731 fish (SE = 109) in 2002 (Table 14).

The objectives of this study were to: (1) estimate the number of coho salmon smolt leaving Nakwasina River in 2002; (2) estimate the marine harvest of coho salmon from Nakwasina River in 2003 via recovery of CWTs applied in 2002; and

(3) estimate spawning escapement in 2003. An additional task of this project was to define the relationship between the estimated escapement and peak foot survey count. Sampling and tagging of smolt in Nakwasina River in 2002 and region wide sampling of adults harvested in 2003 allowed an estimate of smolt abundance in 2002 and harvest in 2003, while sampling and tagging in Nakwasina River during 2003 provided an estimate of spawning abundance.

STUDY AREA

The Nakwasina River (Johnson et al. 2004) is located on the outer coast of Baranof Island in Southeast Alaska (Figure 1). It is about 13 km long, and the anadromous portion ranges between 6 and 30 m wide, and up to 3m deep. It empties into Nakwasina Sound (57° 15'16.8"w/135° 20'41.5"N) about 23 km north of Sitka. Nakwasina River drains approximately 8,600 square hectares and is one of the larger river systems on Baranof Island. Average daily flow rates between 1976 and 1982 ranged from 100 $ft^{3/}s$ to 1,200. Maximum and minimum flows during this time period ranged from a low of 22 $ft^{3/}s$ to a high of 3,400 $ft^{3/}s$.

Nakwasina River is known locally for its freshwater sport fisheries for Dolly Varden *Salvelinus malma* and coho salmon. Because Nakwasina River is easily accessed by boat and it supports one of the largest populations of coho salmon in Sitka Sound, it is one of the few rivers near Sitka that attracts freshwater sport fishing effort for coho salmon. Although the number of respondents was low, estimated annual harvests of coho salmon in Nakwasina Sound, including Nakwasina River, ranged from 0 to 182 fish (Mills 1985; 1994; Howe et al. 1995, 1996, 2001a-d; Jennings et al. *In prep-a-b;* Walker et al. 2003) between 1984 and 2002. Estimated angler effort expended in Nakwasina Sound and River (for all fish species) ranged from 31 to 891 angler days.

In the 1960s, the majority of riparian area in the anadromous portion of Nakwasina River valley was clear-cut to the streambank (Greg Killinger, Personal Communication, Sitka Ranger District, U.S. Forest Service, Sitka). Nakwasina River coho salmon are of special concern because of the potential risk of excessive exploitation in combination with the potential negative impacts to the stock from habitat damage due to logging.

Since 1980, visual surveys have been conducted by foot on Nakwasina River to provide an indication of trends in the annual abundance of coho escapement. Annual peak counts in Nakwasina River represent the largest of five systems surveyed annually in the Sitka area. Surveys conducted from 1980 to 2003 have documented 47 (1986) to 753 (2001) adult coho salmon spawners observed in Nakwasina River (Table 1).

METHODS

There were three major components of this study. A 2-event mark-recapture experiment for a closed population was used to estimate the abundance of coho salmon smolt ≥70 mm FL in Nakwasina River during spring 2002. For this component, coho salmon smolt were sampled and tagged with coded wire tags during spring 2002 (event 1) and recaptured as returning adults in Nakwasina River during fall 2003 to estimate the fraction carrying CWTs (event 2). The second component was sampling the marine harvest. Marine harvests were sampled during the summer and fall 2003 to estimate the tagged fraction and origin of coho captured through commercial fisheries port sampling and recreational fisheries creel survey programs (Oliver 2002 Unpublished; Hubartt et al. 2001). The final component of this study was an open-population mark-recapture experiment conducted fall 2003 in Nakwasina River to estimate the spawning escapement of adult coho. Instream mark and recapture events were integrated with coded wire tag recovery efforts. In addition to the three major components of this study, biweekly foot surveys were conducted to compare with the escapement estimate.

SMOLT TAGGING AND SAMPLING

From April 19 to May 20, 2002, between 50 and 100 G-40 minnow traps were baited with salmon roe and fished daily in Nakwasina River. Traps were fished for 24 hours per day, approximately 6 days per week and checked at least once each day.

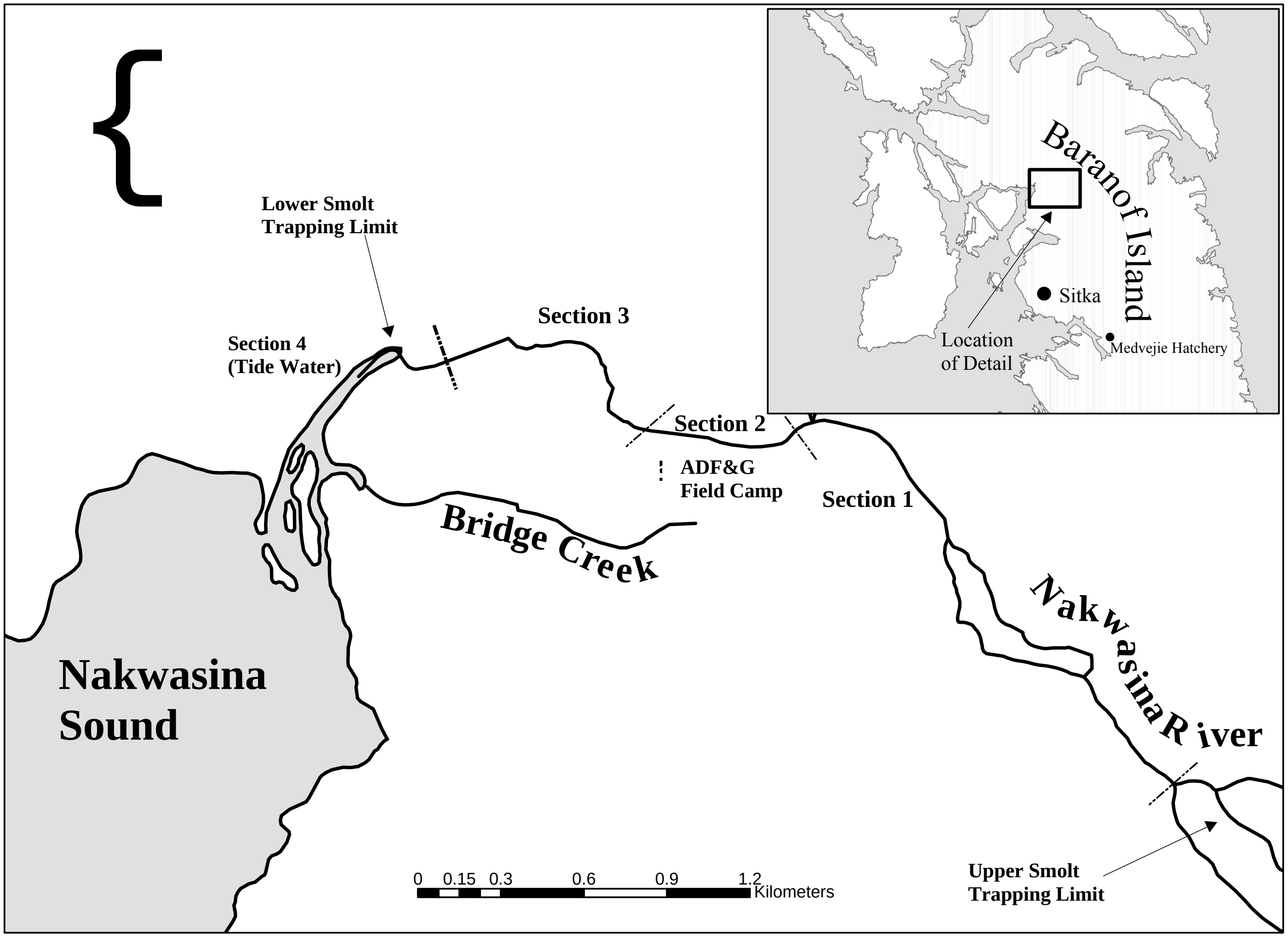

Figure 1.–Map showing Nakwasina River area, including major tributaries and location of ADF&G research sites and stream sections.

Table 1.–Peak escapement counts of coho salmon in the Sitka Area, 1980-2003.

	Sinitsin Creek			St. John Baptist Bay Creek			Starrigavan River			Eagle River			Black River			Nakwasina River		
Year	Survey Type	Peak Survey Date	No. of Coho	Survey Type	Peak Survey Date	No. of Coho	Survey Type	Peak Survey Date	No. of Coho	Survey Type	Peak Survey Date	No. of Coho	Survey Type	Peak Survey Date	No. of Coho	Survey Type	Peak Survey Date	No. of Coho
1980	Foot	30-Sep	39	Foot	9-Oct	26	Foot						Foot	26-Oct	328	Foot	29-Oct	70
1981	Foot	6-Oct	85	Foot	14-Oct	51	Foot	20-Oct	170	Foot	22-Sep	27				Foot	7-Oct	780
1982	Foot	20-Oct	46	Foot			Foot	21-Oct	317									
1983	Foot	27-Sep	31	Foot	13-Oct	12	Foot	6-Oct	45							Foot	14-Oct	217
1984	Foot	10-Oct	160	Foot	10-Oct	154	Foot	10-Oct	385				Helo	3-Oct	425	Foot	17-Oct	715
1985	Foot	15-Oct	144	Foot	8-Oct	109	Foot	11-Oct	193				Helo	7-Oct	1,628	Foot	7-Oct	408
1986	Foot	30-Sep	4	Foot	10-Oct	9	Foot	10-Oct	57	Foot	26-Sep	245	Helo	10-Oct	312	Foot	28-Oct	275
1987	Foot	23-Sep	32	Foot	23-Sep	9	Foot	9-Oct	36	Foot	24-Sep	167	Helo	9-Oct	262	Foot	30-Oct	47
1988	Foot	3-Oct	56	Foot	3-Oct	71	Foot	12-Oct	45	Foot	2-Sep	10	Helo	10-Oct	280	Foot	27-Oct	104
1989	Foot	5-Oct	76	Foot	5-Oct	89	Foot	13-Oct	101	Foot	2-Oct	130	Helo	13-Oct	181	Foot	19-Oct	129
1990	Foot	1-Oct	80	Foot	1-Oct	35	Foot	17-Oct	39	Snorkel	2-Oct	214	Helo	4-Oct	842	Foot	31-Oct	195
1991	Foot	1-Oct	186	Foot	10-Oct	107	Foot	2-Oct	142	Snorkel	17-Oct	454	Helo	17-Oct	690	Foot	25-Oct	621
1992	Foot	23-Sep	265	Foot	14-Oct	110	Foot	12-Oct	241	Snorkel	6-Oct	629	Helo	6-Oct	866	Foot	30-Oct	654
1993	Foot	7-Oct	213	Foot	6-Oct	90	Foot	13-Oct	256	Snorkel	13-Oct	513	Helo	7-Oct	764			
1994	Foot	30-Sep	313	Foot	30-Sep	227	Foot	11-Oct	304	Snorkel	1-Oct	717	Helo	14-Oct	758	Foot	14-Oct	404
1995	Foot	26-Sep	152	Foot	5-Oct	99	Foot	6-Oct	272	Snorkel	5-Oct	336	Helo	27-Sep	1265	Foot	29-Sep	626
1996	Foot	2-Oct	150	Snorkel	2-Oct	201	Foot	17-Oct	59	Snorkel	30-Sep	488	Helo	30-Sep	385	Foot	30-Oct	553
1997	Foot	29-Sep	90	Snorkel	30-Sep	68	Foot	27-Oct	55	Snorkel	30-Sep	296	Helo	30-Sep	686	Foot	14-Nov	239
1998	Foot	1-Oct	109	Snorkel	9-Oct	57	Foot	8-Oct	123	Snorkel	9-Oct	300	Helo	8-Oct	1,520	Foot	2-Nov	653
1999	Snorkel	11-Oct	48	Snorkel	29-Oct	25	Snorkel	8-Oct	166				Helo	4-Oct	1,590	Snorkel	12-Nov	291
2000	Foot	26-Sep	48	Snorkel	26-Oct	32	Snorkel	8-Oct	144	snorkel	29-Sep	108	Helo	2-Oct	880	Foot	8-Nov	419
2001	Foot	5-Oct	62	Snorkel	4-Oct	80	Snorkel	8-Oct	430	snorkel	4-Oct	417	Helo	4-Oct	1,080	Foot	14-Nov	753
2002	Foot	10-Oct	169	Snorkel	2-Oct	100	Foot	10-Oct	227	snorkel	10-Oct	659	Helo	3-Oct	1,994	Foot	5-Nov	713
2003	Foot	29-Oct	102	Snorkel	30-Sep	91	Foot	2-Oct	95	snorkel	9-Oct	375	Helo	2-Oct	1,055	Foot	31-Oct	440
Mean (1980-2003)			114			80			157			293			847			423
5-yr Mean (1998-2003)			103			66			153			390			1,320			523

Traps were set along mainstem banks and in backwater areas of the lower river between the estuary and approximately 6 km upstream. Traps were distributed and redistributed opportunistically to maximize catch by targeting areas of likely rearing habitat, unfished areas, and areas known to produce relatively high catch rates. Coho salmon smolt ≥70 mm were removed from minnow traps and transported to holding pens at the campsite each day. Other species (primarily Dolly Varden) and coho fry <70 mm were counted and released on site.

Every 2-3 days, all live coho salmon smolt ≥70 mm FL were tranquilized with a solution of tricane methane-sulfonate (MS-222) and injected with a CWT with one of the following codes: 04-03-69; 04-05-30; or 04-05-31. Fish were then marked externally by excising the adipose fin. Tagging and marking followed the methods of Koerner (1977). All tagged fish were held overnight in a net pen to test for mortality, tag retention, and adipose fin clip status and released. To test for tag retention, 100 fish were randomly selected and passed through a Northwest Marine Mark IV Portable Sampling Detector™.[1] If tag retention was 98% or greater, all fish were counted, mortalities recorded, and released. If tag retention was 97% or less, all fish were retagged. The number of fish tagged, number of tagging-related mortalities, and number of fish that had shed their tags were recorded on *ADF&G Tagging Summary and Release Information Forms* which were submitted to ADF&G Commercial Fisheries Division (CFD) Tag Lab in Juneau when fieldwork ended.

In 2002, three separate tag codes were used to identify three components of the smolting run. Fish from Nakwasina River that were ≥70 mm but less than 85 mm were tagged with code 04-05-30 while fish ≥85 mm were tagged with code 04-05-31. These two tag codes were used to identify differential survival based on size at smolting. A third tag code (04-03-69) was used for all fish ≥70 mm that were captured in an unnamed tributary to Nakwasina (Figure 1) that is connected only intermittently. This tributary, referred to as "Bridge Creek," empties into salt water approximately ½ km from the outlet of Nakwasina River, except at high tides when the two appear to be connected by a small freshwater passage. This third tag code was used to determine if fish emigrating from this tributary spawn in the mainstem of Nakwasina and to examine differential survival by location of capture.

One in every 15 tagged smolt was measured from snout to fork of tail (FL) to the nearest 1 mm, weighed to the nearest 0.1 g, and sampled for scales. Twelve to 15 scales were removed from the preferred area (Scarnecchia 1979) on the left side of the coho salmon smolt. Scales were sandwiched between two 1 x 3-in microscope slides and numbered consecutively for each sampled fish. Slides were taped together and the number and length of each fish was written on the frosted portion of the bottom slide according to scale position on the slide.

Instream Mark-recapture Sampling, Coded Wire Tag Recovery, and Marine Harvest Sampling

An instream sampling program was designed to periodically mark and recover fish as required for the open-population mark-recapture estimate of adults instream. This was done in conjunction with CWT recovery efforts necessary for the closed population estimate of smolt in 2002. Requirements of the open-population experiment demanded the most intensive sampling efforts; sampling methods were therefore designed for the open population experiment, and sampling for CWT recovery became secondary.

From September 16 through December 10, 2003, sampling occurred during 2- or 3-day periods once each week. Adult coho salmon were captured using a 3.6 x 22.5-m, 3.75-cm mesh beach seine and a 3.0 x 35-m, 7.5-cm mesh gillnet. Hook and line gear was also used to supplement net captures.

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

The stream was divided into four sections (Figure 1). Section 1 extended from river kilometer (rkm) 7.75 downstream to rkm 4.1. The portion of the river upstream of rkm 7.75 was not included because few fish have been observed in this area, and the presence of excessive amounts of woody debris and undercut banks were not conducive to capturing fish. Section 2 extended from rkm 4.1 downstream to rkm 3.7 and section 3 extended from rkm 3.7 to rkm 3.4. Section 4 extended from rkm 3.4 to tide water. Sampling was concentrated in sections 2 and 3 most heavily because two large pools contained the majority of adult coho salmon visible in the river at any one time and enabled use of the more effective beach seine and gillnet. Relatively little sampling occurred below rkm 3.4 because we wished to avoid potential mortality associated with capturing coho salmon that had recently entered fresh water (Vincent-Lang 1993).

All coho captured were examined for presence or absence of their adipose fin. Between September 16 and December 10, all coho missing adipose fins were sacrificed, their heads removed, and sent to the CFD (Commercial Fisheries Division) tag and age lab for dissection and decoding. All captured coho salmon were also examined for an anchor tag and opercle punch combination. All coho salmon absent this combination were measured to the nearest millimeter fork length, tagged with uniquely numbered Floy™ T-Bar anchor tag, given a secondary mark (opercle punch) to permit estimation of tag loss, sampled to determine sex and condition, and sampled to collect scales for aging. Tags were inserted just posterior of and 1 cm below the dorsal fin on the left side of the fish. Secondary marks included various combinations of opercle punches that consisted of 0.6 cm diameter holes. The condition of each fish was determined from external characteristics using the following convention:

Bright: Ocean bright or nearly ocean bright;

Blush: Some color (primarily blush red);

Dark: Dark color (primarily red);

LPS (live post-spawner): Spawned out but not yet dead;

Carcass: Dead spawned fish;

Mortality: Dead unspawned fish.

For fish captured with a Floy™ tag, the location, gear used, tag number, and condition were recorded and the fish was released. If an opercle punch but no anchor tag was present, the fish was recorded as a valid tag recovery (indicating the tag was shed), retagged, and examined for condition. All carcasses that could be retrieved were also inspected for marks, recorded, and removed from the experiment by slashing the left side of the fish. These fish were not counted in subsequent observations.

Sex was determined from external characteristics. Scale samples, consisting of 4 scales from the preferred area near the lateral line on an imaginary line from the insertion of the posterior dorsal fin to the anterior origin of the anal fin (Scarnecchia 1979), were collected and affixed to a gum card in the field. Post-season, scale images were impressed on acetate and ages were determined by examining the impressions under a microscope. Criteria used to assign ages were similar to those of Moser (1969).

Harvest in 2003 of coho salmon originating from Nakwasina River was estimated from fish sampled in commercial and marine sport fisheries. Fisheries personnel with the ADF&G CFD port-sampling program examined commercially caught fish at processing locations and recovered coho with missing adipose fins (Alaska Department of Fish and Game Coded Wire Tag Sampling Program 2002). Similarly, the Division of Sport Fish employed a creel survey program to examine fish caught in the sport fishery (Hubartt et al. 2001). When possible, heads of fish without an adipose fin were removed and sent to the ADF&G Coded Wire Tag and Otolith Processing Laboratory for tag detection and decoding. Because multiple fisheries exploited coho salmon over several months in 2003, harvest was estimated over several strata, each a combination of time, area, and type of fishery. Statistics from the commercial troll fishery were stratified by fishing period and by fishing quadrant. Statistics from the marine sport fishery were stratified bi-weekly.

FOOT SURVEY COUNTS

Adult coho salmon in Nakwasina River were counted visually once every 2 weeks from October 7 to November 21, 2003. Visual counts were conducted by two or three experienced observers wearing polarized lenses during or one day after instream sampling efforts. Only fish positively identified as coho salmon were counted. In braided areas, one observer would walk one braid and the other observer, the adjacent braid. Counts were conducted between the uppermost portion of the survey area (rkm 7.75) and a pool near the high tide mark at rkm 0.25. Uncontrolled variables included observer abilities, weather conditions, and water clarity. Weather conditions, water clarity, and counts were recorded by stream section.

Bridge Creek was examined opportunistically approximately every other week during the course of sampling in an attempt to determine if coho used it for spawning as well as rearing.

ESTIMATE OF SMOLT ABUNDANCE AND SIZE

The mark-recapture experiment was designed so that Chapman's modification to the Petersen estimator (Seber 1982) could be used to estimate smolt abundance.

Several conditions must be met for this estimator to be unbiased for this experiment:

1) there is no recruitment or immigration to the population – only fish that were present in the population during the smolt marking are present in the population of fish inspected for marks as adults;
2) there is no tagging induced behavior or mortality – tagged fish behave the same as untagged fish after the marking event;
3) fish do not lose their marks and all marks are recognizable;
4) tag codes and release locations can be correctly determined for all adult fish observed with missing adipose fin; and
5) all fish marked as juveniles are smolt.

In addition, at least one set of conditions on mortality and sampling must be met. Because significant mortality occurs between sampling events, these conditions must be evaluated and satisfied concurrently. At least one of the following sets of conditions must be met:

S1. all fish have the same probability of surviving between events whether marked or unmarked and across all tagging groups <u>and</u> all fish have an equal probability of being captured and marked during the first event; or

S2. all fish have the same probability of surviving between events whether marked or unmarked and across all tagging groups <u>and</u> either a) complete mixing of marked and unmarked fish occurs prior to the second event or b) all fish have an equal probability of being captured and inspected for marks during the second event; or

S3. all fish have an equal probability of being captured and marked during the first event <u>and</u> either a) complete mixing of marked and unmarked fish occurs prior to the second event or b) all fish have an equal probability of being captured and inspected for marks during the second event.

These conditions were evaluated, where possible, using experimental data and in some cases by indirect knowledge or exercising control over experimental procedures. Equal survival between tagging groups was evaluated using contingency table analysis to test for lack of independence between tagging group and probability of recovery during adult sampling. Contingency table analysis was also used to test for lack of independence between sampling events and occurrence of freshwater age of fish at smolting.

Vincent-Lang (1993) has shown that coho salmon smolts marked as in this project and handled competently suffer no detectable mortality from the experience. Also, there is no reason to believe that capture rates for adults are influenced by the code on a tag imbedded deep within its cartilage. For these reasons, the differences in recovery rates are most likely due to natural differences in survival rates.

For this experiment on Nakwasina River from 2002 to 2003, coho smolt survival to adult size was different ($p = 0.0255$, Table 13) between large ($\geq$85 mm) and small smolt tagged in Nakwasina River and those tagged in Bridge Creek based on tag recovery in adults. However, no significant differences were detected when comparing only large and small smolt tagged in the Nakwasina River ($p = 0.3596$, Table 13). So condition S2 was satisfied for those smolts in the Nakwasina River during the 2002 tagging event.

No test is possible to evaluate if the probability of a smolt being tagged is independent of whether smolt were in Bridge Creek or the Nakwasina River during the tagging event. Therefore, smolts tagged in Bridge Creek were not considered "marked" when estimating abundance.

Under these circumstances, no clearly unbiased estimate of abundance of coho salmon can be calculated. Abundance was estimated using a variant of Chapman's modification to the Petersen estimator:

$$\hat{N} = \frac{(M_1 + M_2 + 1)(C+1)}{(R_1 + \hat{\pi}_1 R_3) + (R_2 + \hat{\pi}_2 R_3) + 1} - 1 \qquad (1)$$

where M is the number of Nakwasina River smolts marked by size group (1 = smaller 70-85 mm FL, 2 = larger >85 mm FL) in 2002, C the number of adults in 2003 inspected for marks, R the subset of C with marks representing a size group of smolts (3 = group unknown), and π_i is the fraction of adults in 2003 that were smaller or larger Nakwasina River smolts in 2002. Smolt tagged in Bridge Creek in 2002 are not used in this estimator, except observed adults are used to estimate π_i parameters.

Estimates of π_i are calculated:

$$\hat{\pi}_i = \frac{T_i}{T_1 + T_2 + T_{BC}} \qquad (2)$$

where T_i is the number of all tags representing a smolt size group (i=1,2) recovered or recaptured from adult salmon regardless of how or where recovered or recaptured and T_{BC} are adults tagged as smolt in Bridge Creek. Therefore, we calculate $T_i = H_i + R_i$ where H_i are all tags from group recovered during sampling of sport and commercial fisheries.

Variance and 95% credibility interval for the estimator (equation 1) were estimated using empirical Bayesian methods (Carlin and Lewis 2000). Using Markov Chain Monte-Carlo techniques, a posterior distribution for $\hat{N}$ was generated by collecting 100,000 simulated values of $\hat{N}'$ which are calculated using equations (1) and (2) from simulated values of equation parameters. Simulated values were modeled from observed data using the following distributions:

observed 28 =
H_1 ~binomial(H_1'/3566, 3566);

observed 8 =
H_2 ~binomial(H_2'/874, 874);

observed 14 =
H_{BC} ~binomial(H_{BC}'/1246, 1246);

observed 145 =
R_1 ~binomial(R_1'/(3566-H_1'), 3566-H_1');

observed 28 =
R_2 ~binomial(R_2'/(874-H_2'), 874-H_2');

observed 24 =
R_{BC} ~binomial (R_{BC}'/(1246-H_{BC}'), 1246-H_{BC}');

and

observed 5 =
R_3 ~binomial(R_3'/202, 202).

At the end of the iterations, the following statistics were calculated:

$$\overline{N}' = \frac{\sum_{b=1}^{100000} \hat{N}'_{(b)}}{100000} \qquad (3)$$

$$\mathrm{var}(\hat{N}) = \frac{\sum_{b=1}^{100000} (\hat{N}'_{(b)} - \overline{N}')^2}{100000 - 1} \qquad (4)$$

Estimates of mean smolt length and weight-at-age and their variances were calculated with standard sample summary statistics (Cochran 1977).

ESTIMATE OF HARVEST

The contribution (r_{ij}) of release group j to a fishery stratum i was estimated as:

$$\hat{r}_{ij} = N_i \left[\frac{m_{ij}}{\lambda_i n_i} \right] \theta_j^{-1}; \qquad \lambda_i = \frac{a_i' t_i'}{a_i t_i} \qquad (5)$$

where:

N_i = total harvest in fishery stratum *i*,

n_i = number of fish inspected in fishery stratum *i* (the sample),

a_i = number of fish which were missing an adipose fin,

a_i' = number of heads that arrived at the lab,

t_i = number of heads with CWTs detected,

t_i' = number of CWTs that were dissected from heads and decoded,

m_i = number of CWTs with code(s) of interest, and

θ_j = fraction of the cohort tagged with code(s) of interest.

When N_i and θ_j are known without error, an unbiased estimate of the variance of (1) can be calculated as shown by Clark and Bernard (1987). However, N_i is estimated with error in our sport fisheries, and θ_j is estimated with error on Nakwasina River since wild stocks are tagged. Because of these circumstances, estimates of the variance of $\hat{r}_{ij}$ based on large sample approximations were obtained using the appropriate equations in Table 2 of Bernard and Clark (1996).

The total harvest for a cohort was calculated as the sum of strata estimates:

$$\hat{H} = \sum_i \sum_j \hat{r}_{ij} \tag{6}$$

$$Var\left[\hat{H}\right] = \sum_i \sum_j v\left[\hat{r}_{ij}\right] \tag{7}$$

SPAWNING ESCAPEMENT

The escapement of adult (1-ocean age) coho salmon in Nakwasina River was estimated from a Jolly-Seber (JS) experiment (Seber 1982) using the model described by Schwarz et al. (1993). Sub-adult (0-ocean age) coho salmon were much smaller than adults and were ignored. Weekly sampling trips spanning the breadth of the river and time of immigration were conducted to mark and recapture adults. Following the work of Sykes and Botsford (1986), repeated recaptures of carcasses "captured" in a decayed condition were

Table 2.– Stream counts including number of coho counted, date, survey conditions, and percentage of total escapement estimate represented by daily count.

Date	Count	Conditions	% of Total Escapement
10/7/2003	126	Visibility Normal Tide High Water Normal	6%
10/21/2003	140	Visibility Normal Tide Intermediate Water Normal	7%
10/31/2003	439	Visibility Normal Tide Intermediate Water Normal	21%
11/21/2003	154	Visibility Normal Tide Intermediate Water Normal	7%

not included. Carcasses found were slashed along the midline to identify them as seen.

In general, escapement (E) is the total number of immigrants (B_i) between the first and last sampling occasion, including fish that enter the system and die between any two sampling occasions (i) and fish that enter before the first sampling occasion (B_0) and after the last sampling occasion (B_s): $\hat{E} = \hat{B}_0 + \ldots + \hat{B}_{s-2} + \hat{B}_{s-1} + B_s$. Because we began sampling while immigration was low and continued it until recruitment was virtually over, we estimated B_0 + B_1 from an estimate of abundance just before the second JS sampling event (N_2) and ignored any small immigration B_{s-1} and beyond as suggested by Schwarz et al (1993). The resulting (albeit biased low) estimator is thus

$$\hat{E} = \hat{N}_2\left(\frac{\log\hat{\phi}_1}{\hat{\phi}_1 - 1}\right) + \hat{B}_2\left(\frac{\log\hat{\phi}_2}{\hat{\phi}_2 - 1}\right) + \ldots + \hat{B}_{s-2}\left(\frac{\log\hat{\phi}_{s-2}}{\hat{\phi}_{s-2} - 1}\right) \tag{8}$$

where $\hat{B}_i$ are JS estimates of the number of fish present at the sample time i+1 which immigrated between i and i+1, $\hat{\phi}_i$ is the survival rate from i to i+1, and the factors $\frac{log(\phi_i)}{\phi_i - 1}$ account for fish that enter and die between samples under the assumption that recruitment is uniformly distributed between samples. The computer program POPAN (Arnason and Schwarz 1995) was used to estimate the JS parameters, and out-of-bounds estimates were constrained to admissible values (Schwarz et al. 1993; Arnason et al. 1996). Variance of escapement was estimated using the delta method and the asymptotic variance and covariances in Schwarz et al. (1993), and expected values of the sampling statistics from POPAN.

Assumptions of the standard (full) JS model (Seber 1982) include:

1. every fish in the population has the same probability of capture in the i[th] sample;
2. every marked fish has the same probability of surviving from the i[th] to the (i+1)[th] sample and being in the population at the time of the (i+1)[th] sample;
3. every fish caught in the i[th] sample has the same probability of being returned to the population;
4. marked fish do not lose their marks between sampling events and all marks are reported on recovery; and
5. all samples are instantaneous (sampling time is negligible).

Chi-square goodness of fit tests were used to test for homogenous capture and survival probabilities by tagged status (Pollock et al. 1990). The first test is equivalent to the Robson (1969) test for short-term mortality. The second test is reported to be better at detecting heterogeneous survival probabilities (Pollock et al. 1990:24). The sum of the chi-squares from each test is an overall test statistic for violations of the first three assumptions above (equal probability of capture, survival, and return to the population).

The equal probability of capture assumption can also be violated if sampling is size or sex selective. Although differences in the size of adult coho salmon are small, a hypothesis that fish of different sizes were captured with equal probabilities was tested by using Kolmogorov-Smirnov (K-S) 2-sample tests (Appendix A3). Sex selective sampling was investigated using a χ^2 test comparing the number of males and females marked with those recaptured. Assumptions 3, 4, and 5 were thought to be robust in this experiment.

AGE AND SEX COMPOSITION

The proportion of the spawning population composed of a given age or sex was estimated as:

$$\hat{p}_j = \frac{n_j}{n} \tag{9}$$

$$Var(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \tag{10}$$

where:

p_j = the proportion in the population in group j;

n_j = the number in the sample of group j; and

n = sample size.

To reduce bias due to inseason changes in age composition, samples were obtained systematically.

ESTIMATES OF TOTAL RUN, EXPLOITATION, AND MARINE SURVIVAL

Estimates of total run (i.e., harvest and escapement) for coho salmon returning to the Nakwasina River in 2003 and the associated exploitation rate in commercial and sport fisheries are based on the sum of the estimated harvest and escapement

$$\hat{N}_R = \hat{H} + \hat{E} \tag{11}$$

The variance of the estimated run was calculated as the sum of the variances for estimated escapement and harvest

$$Var[\hat{N}_R] = Var[\hat{H}] + Var[\hat{E}] \tag{12}$$

The estimate of exploitation rate and variance were calculated using (Mood et al. 1974):

$$\hat{U} = \frac{\hat{H}}{\hat{N}_R} \quad (13)$$

$$Var[\hat{U}] \approx \frac{Var[\hat{H}]\hat{E}^2}{\hat{N}_R^4} + \frac{Var[\hat{E}]\hat{H}^2}{\hat{N}_R^4} \quad (14)$$

The estimated survival rate of smolt to adults and variance were calculated using (Mood et al. 1974):

$$\hat{S} = \frac{\hat{N}_R}{\hat{N}_s} \quad (15)$$

$$Var[\hat{S}] \approx \hat{S}^2 \left[\frac{Var[\hat{N}_R]}{\hat{N}_R^2} + \frac{Var[\hat{N}_s]}{\hat{N}_s^2} \right] \quad (16)$$

RESULTS

SMOLT TAGGING, SAMPLING, AND ABUNDANCE IN 2002

Between April 19 and May 20, 2002, 5,692 coho smolt from Nakwasina River and its tributaries were captured, tagged, and their adipose fins removed. Tag retention was 99.9% with five overnight mortalities. This left 5,686 valid tag releases. Of these 3,566 (63%) were captured in the mainstem of Nakwasina and were ≥70 mm but <85 mm while 874 (22%) were ≥85 mm. Fifteen percent (15%) were fish ≥70 mm captured in Bridge Creek.

Smolt captured in the mainstem of Nakwasina that were age-1 fish (those rearing for one year in fresh water) comprised 98% of sampled smolt and averaged 77.7 mm FL (SE = 0.54) and 4.8 g (SE = 0.11) (Table 3). Age-2 coho smolt from mainstem Nakwasina averaged 92.7-mm FL (SE = 2.96) and 8.1 g (SE = 0.89). The combined catch averaged 78.0 mm FL (SE=0.55) and 4.9 g (SE = 0.11). Average length and weight of captured coho remained approximately the same throughout the tagging effort. From Bridge Creek, age-1 fish comprised 100% of sampled smolt and averaged 81.9 mm FL (SE = 1.18) and 5.2 g (SE = 0.21) (Table 3). No age-2 coho smolt were sampled from Bridge Creek.

The proportions of smolt tagged in 2002 with each of three tag codes were significantly different from those observed in the spawning escapement in 2003 (χ^2 = 12.85, P = 0.0016, Table 13). However, no differences were detected between large and small smolt tagged in the Nakwasina River (χ^2 = 1.39, P = 0.2376, Table 13). Bridge Creek tag groups apparently had lower survival based on rates of recovery of tagged adult fish. Tagged adults from Bridge Creek were not used to estimate smolt abundance because their survival was different from fish tagged in Nakwasina River, and we have no data to evaluate if the probability of a smolt being tagged was the same for both rearing areas.

The point estimate of abundance (eq. 1) based on smolt groups tagged in the Nakwasina River is 22,472. The estimate of SE of the abundance estimate is approximately 1,660, and the 95% credibility interval for the abundance estimate is 19,600 – 26,100. Because tagged fish from Bridge Creek were treated as unmarked fish for this estimate, it is necessary that Bridge Creek smolt have the same survival as Nakwasina River smolt for this estimate to be unbiased. Because fish tagged in Bridge Creek were found to spawn in the mainstem of Nakwasina and no fish were found to spawn in Bridge Creek, Bridge Creek was assumed to be a part of the Nakwasina River coho rearing system. From the tag recovery data (Table 13), it appears that survival of Bridge Creek smolt was approximately 65% of that for Nakwasina River smolt.

While not necessary for abundance estimation, because condition S2 was satisfied, the assumption that the probability of a Nakwasina River smolt being tagged was independent of whether it was large (>85mm FL) or small (≤85mm FL) was tested. The ratio of the catchability coefficients (estimated *A*) for larger to smaller smolt using the methods described in Tydingco (2005) was estimated. For smolt tagged in 2002, the estimated the ratio was 0.903 with an SE of approximately 0.858, which provides no evidence that smolt from the two size groups had different probabilities of being tagged.

Table 3.–Estimated length, weight, and age of coho salmon smolt from Nakwasina River and Bridge Creek in 2002.

	Nakwasina						Bridge Creek	
	Age 1		Age 2		Combined		Age 1	
Statistic	Length*	Weight*	Length	Weight	Length	Weight	Length	Weight
Mean	77.7	4.8	92.7	8.1	78.0	4.9	81.9	5.2
Standard Error	0.54	0.11	2.96	0.89	0.55	0.11	1.18	0.21
Sample Size	158	158	3	3	161	161	52	52

*Length measured to the nearest millimeter and weight to the nearest 10th gram.

% age 1 fish in Nakwasina = 98% % age 1 fish in Bridge Creek = 100%

INSTREAM MARK-RECAPTURE SAMPLING AND CODED WIRE TAG RECOVERY

The CWT tagged fraction of adult coho salmon sampled in Nakwasina River during 2002 was 0.225. Of the 901 adult coho salmon examined, 202 had an adipose fin clip.

The proportion of freshwater age-1 fish was not significantly different (χ^2 = .2031, P ≤0.6522) between smolt sampled in 2002 and adults sampled inriver during 2003 (Table 4). Both groups were predominately (≥98%) freshwater age-1 fish.

Table 4.–Number of freshwater age-1 and freshwater age-2 coho salmon smolt and adults in 2000 through 2003.

	Freshwater Age 1	Freshwater Age 2	Proportion Age-2	χ^2	P-value
Adult 2003	681	13	0.019	0.203	0.6522
Smolt 2002	210	3	0.014		
Adult 2002	663	25	0.036	18.527	0.0000
Smolt 2001	368	41	0.100		
Adult 2001	701	19	0.026	0.268	0.6043
Smolt 2000	397	13	0.032		

.

Length distributions of adult coho salmon captured in 2003 in Nakwasina River were not different between gear type used for capture, capture and recapture, or time of capture (K-S Tests, Figure 2). Female mean length (634 mm (SE = 1.8)) was significantly longer than male (mean length 613 mm (SE = 2.31)). A higher proportion of males were captured at all locations except location 3 (approximately the middle of our sampling area) than the other 3 sections (χ^2 = 25.7 P ≤0.000, Table 5).

Most (831) adult coho captured in Nakwasina River in 2003 were captured with either the beach seine or gillnet, while 64 were captured with hook and line. Hook and line gear was moderately effective at capturing fish but only when water conditions allowed for sighting fish. The use of a beach seine seemed to be the most effective means of capture.

CONTRIBUTION OF SMOLT TAGGED IN 2002 TO MARINE FISHERIES IN 2003

In 2003, 46 CWTs from the Nakwasina River and Bridge Creek were recovered from 220,916 coho salmon sampled in commercial and sport fisheries and four additional CWTs were recovered incidentally (Appendix A1). Thirty-seven coho salmon bearing CWTs with a Nakwasina River code were recovered randomly from Southeast Alaska's commercial troll fisheries, 28 of which had Nakwasina River (not Bridge Creek) tag codes and could be used to estimate commercial harvest. All of these fish were caught in the Northwest Quadrant (Figure 3) of Southeast

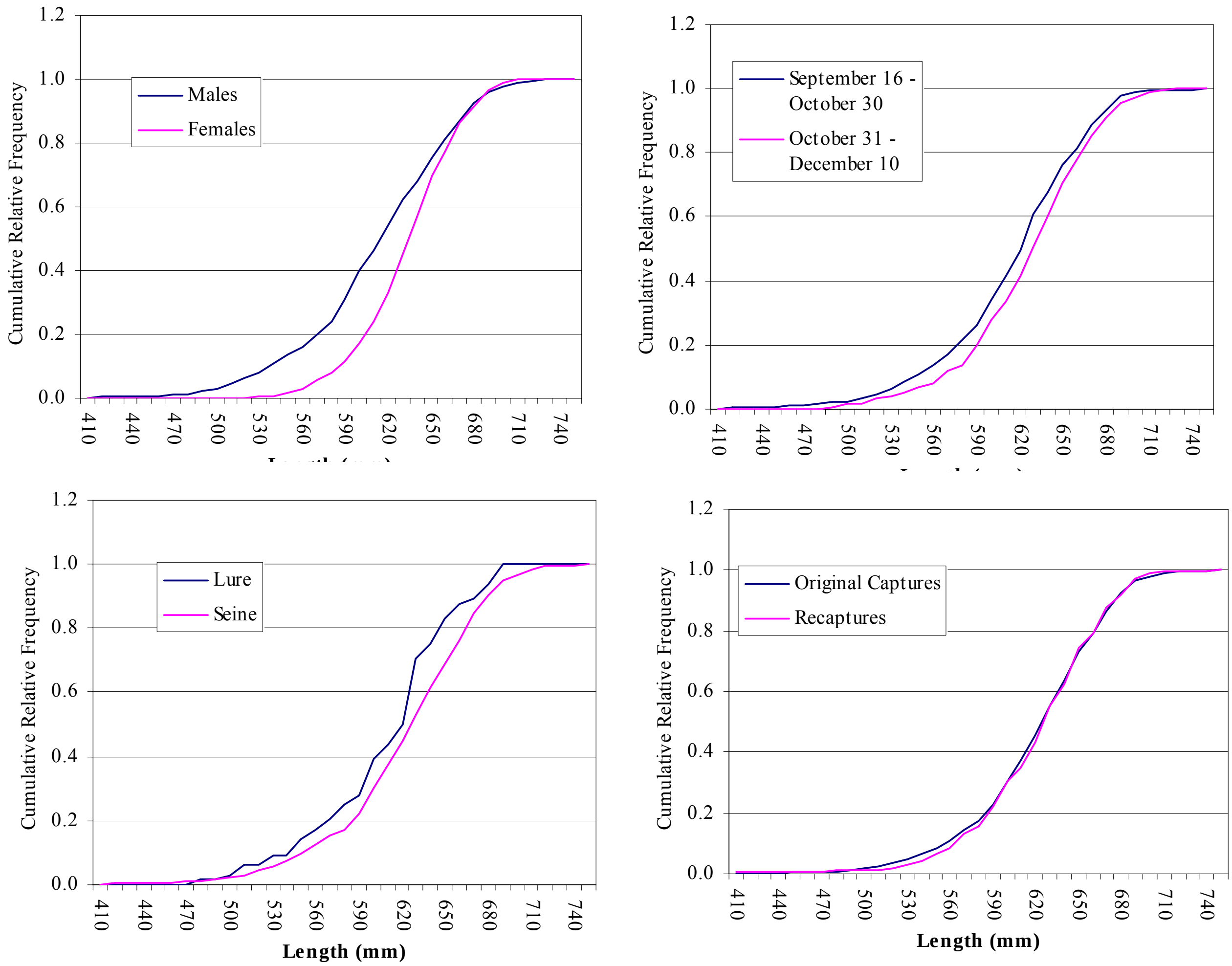

Figure 2.– Cumulative length frequency distributions to test for differences in lengths of captured coho by sex, time, gear, and capture or recapture**.**

Alaska between July 3 and October 1, 2003. Nine coho salmon bearing CWTs with a Nakwasina River code were recovered in the Sitka sport fishery between July 19 and September 16, 5 of which had Nakwasina River tag codes. No fish were randomly recovered in the commercial gillnet or seine fisheries.

The estimated harvest of Nakwasina River coho salmon in sampled marine fisheries in 2003 was 604 (SE = 110; Table 6). Nakwasina coho contributed less than 1% of the combined sport and commercial troll harvest (773,556 (Table 6)) for the areas in which Nakwasina River fish were recovered. The total contribution to the sport fishery by Nakwasina coho was estimated at 115 fish. Sport-caught Nakwasina coho comprised 19.0% of the harvest of that stock in the sampled marine fisheries, but relative contributions were higher for the sport harvest (0.16%) than the troll harvest (0.07%). Freshwater harvest of coho salmon in Nakwasina River will not be available until the Division of Sport Fish publishes the results of its annual mail-out angler survey.

Coho salmon bearing CWTs with a Nakwasina River code recovered in the commercial and sport fisheries averaged 650 mm FL (SE = 6.99).

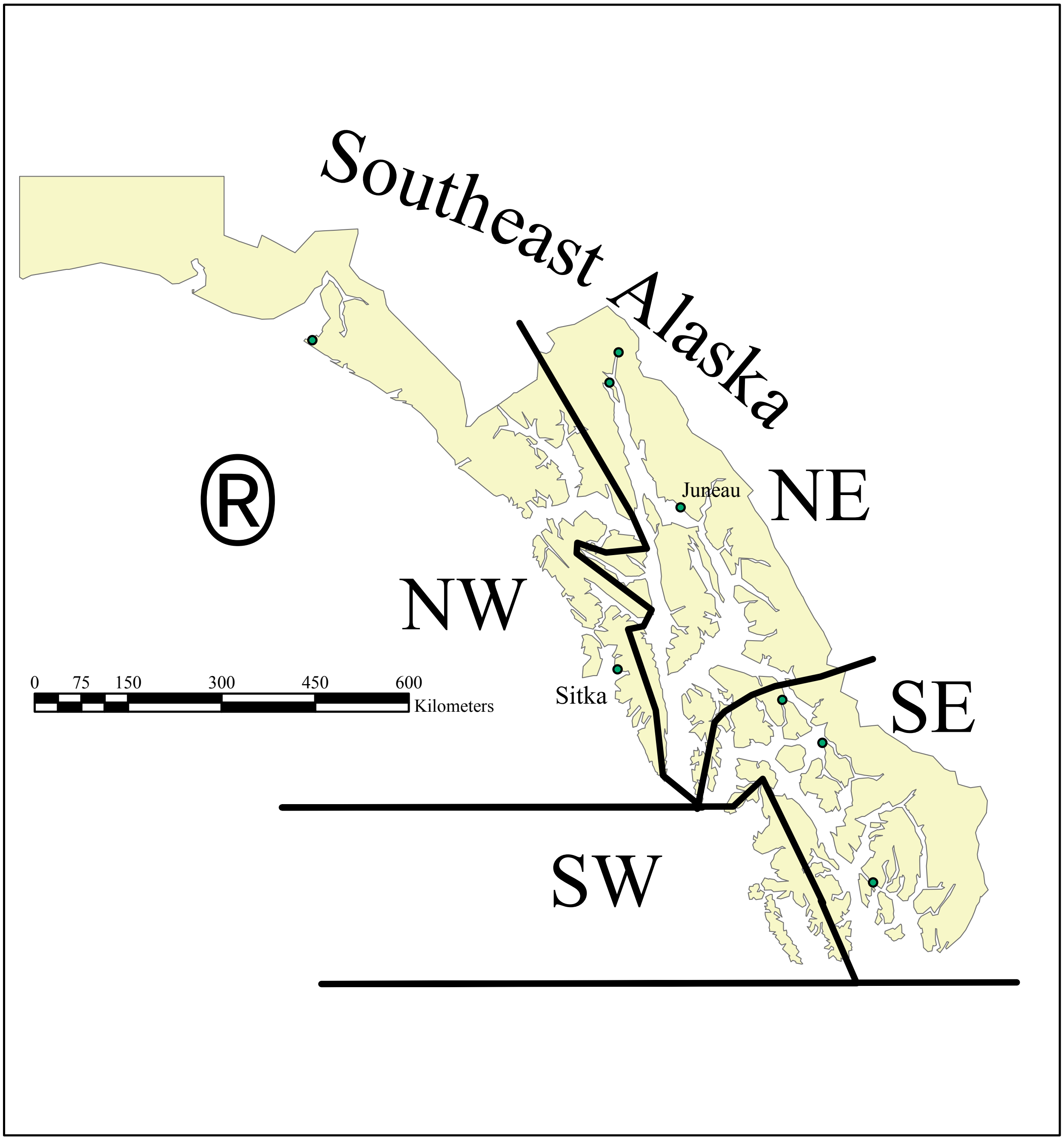

Figure 3.–Map of Southeast Alaska showing the boundaries for CWT quadrants.

Table 5.–Differences in sex composition between capture type, gear, and location.

Capture	Females	Males	% Males	$\chi 2$	p-value
Captured	369	532	59.0%	4.14	0.0419
Recapture	70	140	66.7%		
Gear Type					
Hook and Line	30	34	53.1%		
Seine	144	278	65.9%	15.14	0.0005
Tangle Net	192	217	53.1%		
Location					
Section 1	100	145	59.2%	25.74	0.0000
Section 2	120	247	67.3%		
Section 3	112	95	45.9%		
TW	37	45	54.9%		

ESTIMATED SPAWNING ESCAPEMENT, TOTAL RUN, AND MARINE SURVIVAL

Coho salmon were marked and recaptured in all 13 weeks of the study. Altogether, 901 individual adults were captured and examined, and 260 (Table 7) recaptures were made, which were comprised of 213 individual fish (several fish were recaptured multiple times). Only six recaptured fish had lost their numbered tag as evidenced by the operculum punches. A total of 215 fish were sacrificed for their CWTs or died on capture. One fish died upon recapture and 47 tagged fish were recaptured more than once during one sampling period.

Instream abundance peaked at 1,404 adults in week 7 and declined to 22 fish in week 13 (Table 8). Period-to-period survival rates varied from 1.0 (constrained) to 0.214 (Table 8).

The estimated spawning escapement of coho salmon in Nakwasina River was 2,063 fish (SE = 233). Goodness of fit tests (Table 9) suggested the JS model fit the data well. Three estimates of survival and seven estimates of recruitment were constrained to yield admissible (realistic) values during the estimation procedure (Table 8).

Thirty-one percent (31%) of the sample was captured or recovered in section 1, 41% at location 2, 21% at location 3, and 7% at tidewater (Table 10). In total, 22.3% of the fish inspected for Floy™ tags had either a Floy™ tag or a secondary mark. The probability of capturing a tagged fish was significantly higher in section 1 than in the other sections (Table 10).

Based on an escapement estimate of 2,063, a coho salmon marine harvest of 604 fish, and smolt abundance of 22,472, we estimated the total run in 2003 to be 2,667 (SE = 258) and ocean survival to be 11.9% (SE = 1.4%). Total exploitation was estimated to be 22.6% (SE = 3.7%).

VISUAL COUNTS

Visual counts were conducted on Nakwasina River on four occasions in 2003 (Table 2). The peak count (439) occurred October 31 (Table 2) and represented 21% of the estimated total escapement. The area between river kilometer 7.75 (the upper end of the sampling area) and river kilometer 13.0 was inspected for coho in November, but few fish were seen.

Table 6.–Estimated harvest of adult Nakwasina River coho salmon (tag codes 04-05-30 and 04-05-31) in sampled in sport and commercial fisheries in 2003.

TROLL FISHERY											
Period	Dates	Quadrant	Estimated Harvest	Inspected	a	a'	t	t'	m	r	SE{r}
3	6/30-8/10	NW	261,309	73,397	1,389	1,377	1,142	1,140	1	18.2	17.70
4	8/11-10/5	NW	438,499	128,461	3,480	3,452	2,961	2,959	27	470.6	94.42
Subtotal troll fishery			699,808	201,858	4,869	4,829	4,103	4,099	28	488.8	95.97

SPORT FISHERY											
Bi-week	Dates	Area	Estimated Harvest	Inspected	a	a'	t	t'	m	r	SE{r}
11-15	5/26-8/3	SITKA	32,140	8,630	210	209	185	183	1	19.1	18.64
16-17	8/4-8/31	SITKA	37,233	9,846	307	305	274	274	3	57.8	32.68
18-19	9/1-9/28	SITKA	4,375	582	15	15	15	15	1	38.0	37.55
Subtotal sport fishery			73,748	19,058	532	529	474	472	5	115.0	53.16
Total All Fisheries			773,556	220,916	5,401	5,358	4,577	4,571	33	604	110

DISCUSSION

SMOLT ABUNDANCE AND ADULT HARVEST

To estimate smolt abundance and adult harvest we assumed several conditions must be met for this estimator to be unbiased for this experiment:

1. there is no recruitment or immigration to the population – only fish that were present in the population during the smolt marking are present in the population of fish inspected for marks as adults;
2. there is no tagging induced behavior or mortality – tagged fish behave the same as untagged fish after the marking event;
3. fish do not lose their marks and all marks are recognizable;
4. tag codes and release locations can be correctly determined for all adult fish observed with missing adipose fin;
5. all fish marked as juveniles are smolt, and

either:

S1. all fish have the same probability of surviving between events whether marked or unmarked and across all tagging groups <u>and</u> all fish have an equal probability of being captured and marked during the first event; or

S2. all fish have the same probability of surviving between events whether marked or unmarked and across all tagging groups <u>and</u> either a) complete mixing of marked and unmarked fish occurs prior to the second event or b) all fish have an equal probability of being captured and inspected for marks during the second event; or

S3. all fish have an equal probability of being captured and marked during the first event <u>and</u> either a) complete mixing of marked and unmarked fish occurs prior to the second event or b) all fish have an equal probability of being captured and inspected for marks during the second event.

We believe that most of these assumptions were satisfied for smolt tagged in the Nakwasina River, but we could not determine that necessary assumptions were satisfied for all tagged smolt including those tagged in Bridge Creek. We could detect no differences in survival between large and small smolt tagged in the Nakwasina River but it appears that survival was lower for smolt tagged in Bridge Creek.

No significant difference was detected between the probabilities that large and small smolt were caught and tagged in the Nakwasina River. We could not compare the probability of tagging Bridge Creek smolt with that of Nakwasina River smolt. Further, we have no expectation that the probabilities are similar because tagging occurred in geographically separate areas. Smolt capture and tagging occurred throughout the emigration, within most of the available smolt habitat, and was also accomplished with minnow traps that would capture a wide range of smolt sizes encompassing the entire geographic range of smolt observed in the river. Smolt tagging occurred both just prior to and during the smolting migration. Because approximately equal effort occurred throughout the emigration, later running smolt may have had a higher probability of capture. Similarly, recovery effort was expended throughout most of the run of returning adults, but not in exact proportion to fish abundance, and a small number of fish probably returned earlier or later than the tag recovery sampling.

Table 7.–Summarized mark-recapture data for Nakwasina River coho salmon 2003.

Week	Number Captured	Number Marked Caught in *mi*	Losses on Capture	Subsequently Recaptured
38	10			
39	34		8	8
40	85	2	23	35
41	64	20	16	23
42	53	18	12	23
43	106	13	23	55
44	123	15	32	35
45	204	42	48	48
46	125	65	31	16
47	38	23	6	8
48	25	32	10	5
49	29	14	5	3
50	5	16	1	1
Totals	901	260	215	260

Notation follows that in Seber (1982).

Table 8.–Jolly Seber estimates of abundance (N), survival (ϕ), and recruitment (B) of adult coho salmon at Nakwasina River, 2003.

Week(s)	Dates	$\hat{N}$	$SE(\hat{N})$	$\hat{\phi}$	$SE(\hat{\phi})$	$\hat{B}$	$SE(\hat{B})$
1	9/19-9/20	44	7	1.000	0.000	0	0
2	9/21-9/27	44	7	0.305	0.111	311	51
3	9/28-10/4	322	52	1.000	0.000	0	0
4	10/5-10/11	299	52	0.460	0.086	86	46
5	10/12-10/18	216	51	0.846	0.143	567	196
6	10/19-10/25	739	204	1.000	0.000	688	206
7	10/26-11/1	1,404	118	0.891	0.120	0	0
8	11/2-11/8	1,223	131	0.920	0.196	0	0
9	11/9-11/15	1,081	203	0.432	0.136	0	0
10	11/16-11/22	453	118	0.553	0.213	0	0
11	11/23-11/29	247	79	0.405	0.175	41	21
12	11/30-12/6	138	44	0.214	0.072	0	0
13	12/7-12/10	29	6				

Table 9.– Summary of goodness-of-fit tests for homogeneous capture/survival probabilities by tag group. Overall chi-squares are the sum of the individual test statistics**.**

	Component 1			Component 2		
Period	χ^2 τατσ	df	P-value	χ^2 τατσ	df	P-value
2	-	-	-	-	-	-
3	0.00	1	1.00	1.33	1	0.25
4	4.53	1	0.03	3.83	1	0.05
5	1.21	1	0.27	2.34	1	0.13
6	0.00	1	0.96	0.07	1	0.80
7	0.32	1	0.57	0.78	1	0.38
8	1.22	1	0.27	0.13	1	0.72
9	1.43	1	0.23	0.02	1	0.89
10	0.17	1	0.68	0.35	1	0.55
11	0.80	1	0.37	0.53	1	0.47
12	0.79	1	0.37	-	-	-
Overall	10.47	10	0.40	9.38	9	0.40

Although the assumption about mixing cannot be tested, coho salmon most likely mixed within or across stocks during their extended time (14 months) at sea. This should provide adequate mixing of the population. In Nakwasina River catches, the fraction of adult coho salmon with marks (missing an adipose fin) did not vary significantly over time (Table 11). This also indicates that at least one of the conditions in Assumption 1 was satisfied.

Assumption 1 required that there was no recruitment to the population between years. Because almost all wild coho salmon return to their natal streams and sampling only occurred in the river, there was probably no appreciable recruitment to the stock between marking and recovery. We believe the presence of stray coho salmon reared at Medvejie hatchery is possible but unlikely given the geographical distance between the two sites. Additionally, no coho from Medvejie hatchery have been recovered in Salmon Lake, which is much closer to the hatchery release area.

The smolt estimate of 22,472 may be biased low. Unfortunately, attempts to assess the bias are, at best, speculative because no data are available to measure differences in probability of tagging between the two rearing areas. However, if the probabilities of a smolt being tagged were approximately the same for both Nakwasina River and Bridge Creek, then 20-25% of the smolt in the Nakwasina system were in Bridge Creek when tagging was conducted and we can project that the true smolt abundance was 1.10 to 1.15 times our estimated value. If Bridge Creek smolt were tagged at a higher rate than Nakwasina River smolt, the potential bias is not so severe. If Bridge Creek smolt were tagged at a lower rate than Nakwasina River smolt, the potential bias is, of course, greater than we projected.

Unlike tagged 2002 and 2001 smolt, coho smolt tagged in 2000 and recovered in 2001 in escapement sampling exhibited a recovery rate similar to their tagged rate (Table 13).

The smolt-to-adult survival rate of 11.9% in 2003 is low, but comparable to other systems in the region (13.7% in Hugh Smith Lake, 25% in Auke Creek, 19.1% in Berners River (Leon Shaul, personal communication)). In the Taku River, smolt to adult survival in 2002 was 11.2% (Ed Jones, personal communication). The average smolt to adult survival rate between 2000-2003 of

Table 10.–Results of χ^2 tests for differences in tagged rate between sections.

Location	Untagged	Tagged	Total	% of total captures by area
1	245	118	363	31.3%
2	367	104	471	40.6%
3	207	38	245	21.1%
Tide Water	82		82	7.1%
Total	901	260	1,161	
Sections 1-3	χ^2	=24.96	P<	0.0000

9.5% (Table 14) is also similar, but again lower than, other streams in Southeast Alaska. The average smolt to adult survival rate in five other coho indicator stocks are shown in Table 16. Because of the low average smolt-to-adult survival rate in Nakwasina River in 2000-2002 (average = 8.7%) extra care was taken in spring 2002 to insure smolt were given an adequate opportunity to recover and smolt naturally. Because survival remained relatively low in 2002-2003 (11.9%), we assume that Nakwasina River coho have a naturally lower survival rate.

It is unlikely that smolt regenerated the clipped adipose fin that identified the fish as containing a tag. In conjunction with tag retention and overnight mortality tests, we examined adipose fin clips on smolt. All smolt examined appeared to have good fin clips. Also, all adult coho examined had well defined or a complete absence of an adipose fin.

Table 11.–Proportion of recovered Nakwasina River adult coho observed with and without adipose fin clips.

Date	No Clip	Clip Observed	Tagged Proportion
16-Sep	2		0.00
17-Sep	8		0.00
22-Sep	13	3	0.19
23-Sep	14	4	0.22
29-Sep	14	2	0.13
30-Sep	9	3	0.25
1-Oct	43	14	0.25
6-Oct	29	13	0.31
7-Oct	19	3	0.14
13-Oct	4	1	0.20
14-Oct	39	9	0.19
20-Oct	46	7	0.13
21-Oct	6	1	0.14
24-Oct	31	15	0.33
30-Oct	49	17	0.26
1-Nov	43	14	0.25
2-Nov	49	11	0.18
3-Nov	30	11	0.27
4-Nov	29	7	0.19
5-Nov	48	19	0.28
10-Nov	51	15	0.23
11-Nov	44	15	0.25
17-Nov	11	2	0.15
19-Nov	21	4	0.16
24-Nov	13	5	0.28
25-Nov	4	3	0.43
3-Dec	7	1	0.13
4-Dec	18	3	0.14
10-Dec	4	1	0.20
Total	698	203	0.225

The smolt abundance estimate in 2002 is lowest estimate since the project began in 1998 (Table 14).

In future tagging events, extra care should be taken to ensure that any potential effects of tagging are minimized. Recommendations for future tagging include: 1) releasing smolt in side tributaries with extensive available rearing habitat as opposed to mainstem areas with higher velocities; 2) minimizing transport distances by centralizing the tagging and holding site; 3) returning tagged smolt to locations near their capture site; 4) tagging and sampling all fish within 48 hours of capture to ensure fish are not held for periods greater than 72 hours, including overnight mortality testing; and 5) estimating the true contribution and survival of Bridge Creek smolt in the Nakwasina adult escapement. This may be done by installing a weir on Bridge Creek through the smolting migration and either counting each fish that smolts through the weir or conducting a mark recapture experiment to estimate the number of smolt in Bridge Creek prior to the smolting migration.

ADULT ESCAPEMENT IN 2003

There were no indications to suggest problems with the abundance estimate; tag loss was low (1.5%), sampling rates were high and assumptions of the JS experiment were met, and the JS model fit the data. Additionally, marking did not appear to affect the behavior or movement of fish, as marked fish were observed spawning with or near unmarked fish throughout the study.

A higher rate of recapture was observed for males than females during the adult escapement. This may have been due to error in determining the sex of fish early in the run. Because the secondary maturation characteristics had not fully developed earlier in the run, it is possible that some fish were misidentified as females. When recaptured, fish previously identified as females may have been identified as males. This would lead to an indication that a higher proportion of males were recaptured.

Some adult coho may not have had the same probability of capture as others. Differences were found between the fractions of fish carrying marks in upriver and downriver locations (Table 10.). Because all areas were sampled approximately equally, fish had a greater chance of being sampled as it moved from downriver to upriver.

The fact that the JS estimations were constrained to yield admissible values suggests violation of assumptions of some kind were experienced in the experiment, although the escapement estimate is unlikely to be seriously effected by this problem (Schwarz et al. 1993). One explanation for the difficulty is temporary emigration and re-immigration of fish from the study area, perhaps due to stress associated with handling and tagging. In 2001, a Floy™ tagged fish with fresh herring in its belly was returned by a fisherman that captured the fish in the Nakwasina River. This indicates that some fish do temporarily emigrate and re-immigrate after being tagged.

Recoveries of Floy™ tagged fish in 2003 showed that fish tagged at tidewater had a higher rate of recapture than fish tagged in upstream locations (Table 15). This may have been the result of many factors including: 1) fish may have been present longer in the study area as they moved upstream, 2) a fish tagged near salt water may have been captured earlier in its spawning migration and thereby have a stream-life expectancy greater than a fish tagged upstream, 3) the capture conditions at tidewater may have been more conducive to physiological fish recovery than in the mainstem river (due to low stream flow rate and large recovery area). These recovery rates indicate that problems associated with mortality near the saltwater/freshwater interface (Vincent-Lang et al. 1993) were not present during our study. These results show that incorporating the saltwater/freshwater area will not likely negatively affect fish survival.

VISUAL COUNTS

Nakwasina River is similar to other clearwater streams in the area, and the relationship between the peak observer count and the total escapement is similar to that found in Steep Creek near Juneau, Alaska (McPherson et al. 1996; Jones III and McPherson 1997). The ability to count spawning salmon depends on many factors, including the observer, weather, water clarity, canopy cover, pool-to-riffle ratio, the density of fish, the amount of undercut banks, and the ecology, behavior, size, and color of salmon (Jones III 1995).

HARVEST SAMPLING

To assess the adequacy of sampling rates in the purse seine and gillnet fisheries, we examined troll harvests within Southeast Alaska where Nakwasina River coho salmon recovery occurred (Table 12). The sampling rate for troll fisheries in the Northwest Quadrant ranged from 34% (District 113) to 9% (District 154). Because not all fisheries were sampled, it is likely that Nakwasina River coho salmon harvest was underestimated in some fisheries.

Table 12.–Numbers of fish harvested and sampled for CWT recovery for districts in which Nakwasina River coho were recovered.

District	Gear Type	Fish Harvested	Fish Sampled	Proportion Sampled
113	Troll	389,386	134,003	0.34
114	Troll	185,541	39,525	0.21
116	Troll	12,765	1,939	0.15
154	Troll	6,911	653	0.09
		594,603	176,120	0.20

Table 13.–Numbers and χ^2 tests for independence for smolt and adult coho from the Nakwasina River and Bridge Creek between 2000-2003 by tag group.

Year	≥70 mm	≥85 mm	Bridge Creek	Total	≥70 mm	≥85 mm	Bridge Creek	
Nakwasina Spring Smolt Releases					Percentage of Total			
2000	5,446	1,831	3,042	10,319	53%	18%	29%	100%
2001	6,979	1,434	1,986	10,399	67%	14%	19%	100%
2002	3,566	874	1,246	5,686	63%	15%	22%	100%
Adult Escapement Recoveries					Percentage of Total			
2001	75	35	40	150	50%	23%	27%	100%
2002	146	39	15	200	73%	20%	8%	100%
2003	145	28	24	197	74%	14%	12%	100%
Adult Fisheries Recoveries					Percentage of Total			
2001	48	22	29	99	48%	22%	29%	100%
2002	27	22	5	54	50%	41%	9%	100%
2003	28	8	14	50	56%	16%	28%	100%
All Adults Combined					Percentage of Total			
2001	123	57	69	249	49%	23%	28%	100%
2002	173	61	20	254	68%	24%	8%	100%
2003	173	36	38	247	70%	15%	15%	100%

Component 1	Component 2	$\chi2$	p
Smolt 2000	All Adults 2001	4.63	0.0986
Smolt 2000	Adult Escapement 2001	3.11	0.1910
Adult Fisheries 2001	Adult Escapement 2001	0.21	0.9011
Smolt 2001	All Adults 2002	36.95	0.0000
Smolt 2001	Adult Escapement 2002	20.24	0.0000
Adult Fisheries 2002	Adult Escapement 2002	11.46	0.0033
Smolt 2002	All Adults 2003	7.34	0.0255
Smolt 2002	Adult Escapement 2003	12.85	0.0016
Adult Fisheries 2003	Adult Escapement 2003	8.34	0.0155
Nak. Smolt 2002	Nak. Adults 2003	0.84	0.3596
Nak. Smolt 2002	Nak. Ad. Escapement 2003	1.39	0.2376
Nak. Ad. Fisheries 2003	Nak. Ad. Escapement 2003	0.76	0.3828

Table 14.–Summaries of estimated smolt abundance, harvest, escapement, exploitation, and stream counts in the Nakwasina River 1998-2003.

Year	Smolt Tagged	Smolt Abundance Estimate	Smolt SE	Adult Esc	Adult Esc SE	Harvest	Harvest SE	Exploitation	Theta	Stream Survey Peak Count	Proportion of Escapement Estimate	Estimated Marine Survival
1998	9,985	102,794	15,255	-	-	-	-	-	-	653	-	
1999	3,971	47,571	6,402	-	-	1,983	605	-	0.095	291	-	
2000	10,228	46,575	2,722	2,000	261	1,219	231	0.37	0.082	419	0.21	6.8
2001	10,381	39,461	3,057	2,992	510	1,439	155	0.325	0.221	753	0.252	9.5
2002	5,286	22,472	1,660	3,141	661	731	109	0.178	0.237	713	0.227	9.8
2003	15,761	-	-	2,063	233	604	110	0.226	0.203	440	0.213	11.9
Averages	9,269	51,775	5,799	2,549	416	1,195	242	0.276	0.168	523	0.226	9.5

Table 15.–Numbers of fish recaptured by location of original tagging and location of recapture.

	Original Tag Location			
Location of Recapture	1	2	3	Tide Water
1	39	42	21	12
2	3	54	25	21
3	2	15	17	b4
Totals	45	113	66	37
Total Number of Fish Tagged	245	365	207	82
Proportion Recovered	0.184	0.310	0.319	0.451

Table 16.–Smolt to adult survival rate for coho indicator streams around Southeast Alaska .

	Return Year				
Stream	2000	2001	2002	2003	Average
Auke Creek	18.5	28.3	26.8		24.5
Berners River	11.7	11.8	18.9		14.1
Taku River	8.1	9.1	13.2		10.1
Ford Arm	12.8	8.2	14.7	17	13.2
Hugh Smith Lale	6.6	13.5	14.5	14	12.2
Unuk River	3.8	11.4	9.3		8.2
Nakwasina River	6.8	9.5	9.8	11.9	9.5

(Leon Shaul, Personal Communication.)

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APPENDIX A

Appendix A1.–Recoveries of coded wire tags originating from Nakwasina River coho salmon during 2003.

Head	Tag Code	Gear Class	Recovery Date	Stat Week	Quadrant	District	Sub-District	Length	Survey Site	Sample
Random Recoveries										
124521	40531	TROLL	7/3/2003	27	NW	113	91	603	PELICAN	3010121
225771	40369	TROLL	8/22/2003	34	NW	116	11	608	PELICAN	3010240
226153	40369	TROLL	8/28/2003	35	NW			648	PELICAN	3010253
226224	40369	TROLL	9/1/2003	36	NW	113		673	PELICAN	3010262
226309	40530	TROLL	9/8/2003	37	NW	114	21	722	PELICAN	3010275
226352	40530	TROLL	9/9/2003	37	NW	113	91	685	PELICAN	3010278
226386	40530	TROLL	9/9/2003	37	NW	113	91	675	PELICAN	3010280
226443	40531	TROLL	9/10/2003	37	NW	114	21	635	PELICAN	3010287
226527	40530	TROLL	9/18/2003	38	NW	113	91	672	PELICAN	3010306
226586	40530	TROLL	10/1/2003	40	NW	113	91	646	PELICAN	3010324
226584	40530	TROLL	10/1/2003	40	NW	113	91	692	PELICAN	3010324
226587	40530	TROLL	10/1/2003	40	NW	113	91	703	PELICAN	3010324
226589	40531	TROLL	10/1/2003	40	NW	113	91	595	PELICAN	3010325
55803	40369	TROLL	9/5/2003	36	NW	114	21	667	ELFIN COVE	3020196
27125	40530	TROLL	9/22/2003	39	NW	114	21	680	ELFIN COVE	3020244
235158	40530	TROLL	8/20/2003	34	NW	113		484	SITKA	3031068
220834	40530	TROLL	8/25/2003	35	NW	113	45	693	SITKA	3031093
220897	40369	TROLL	8/26/2003	35	NW	113	45	598	SITKA	3031106
235668	40530	TROLL	9/6/2003	36	NW	113		635	SITKA	3031144
235679	40530	TROLL	9/6/2003	36	NW	113	45	694	SITKA	3031146
235848	40530	TROLL	9/7/2003	37	NW	113	41	664	SITKA	3031156
235841	40530	TROLL	9/7/2003	37	NW	113	41	697	SITKA	3031156
235869	40369	TROLL	9/7/2003	37	NW	154		657	SITKA	3031159
235892	40369	TROLL	9/8/2003	37	NW	113	45	617	SITKA	3031162
235921	40530	TROLL	9/8/2003	37	NW	113	45	614	SITKA	3031163
235593	40530	TROLL	9/9/2003	37	NW	113	45	650	SITKA	3031174
235953	40531	TROLL	9/10/2003	37	NW	113	61	624	SITKA	3031181
235368	40531	TROLL	9/13/2003	37	NW	113	61	582	SITKA	3031197
235392	40531	TROLL	9/16/2003	38	NW	113	45	528	SITKA	3031205
248203	40530	TROLL	9/17/2003	38	NW	113	45	678	SITKA	3031209
248142	40530	TROLL	9/18/2003	38	NW	113	45	657	SITKA	3031227
248151	40369	TROLL	9/30/2003	40	NW	113	45	674	SITKA	3031249
248154	40530	TROLL	9/30/2003	40	NW	113	45	715	SITKA	3031250
207947	40369	TROLL	9/21/2003	39	NW				JUNEAU	3040505
205576	40530	TROLL	9/6/2003	36	NW	113	11	650	PORT ALEXANDER	3080173
247544	40530	TROLL	9/10/2003	37	NW	113	91	655	HOONAH	3110204
84780	40530	TROLL	9/11/2003	37	NW			668	YAKUTAT	3140057
242329	40530	SPORT	7/19/2003	29	NW	113	41	640	SITKA	3035362
242799	40369	SPORT	7/23/2003	30	NW	113	41	610	SITKA	3035392
254613	40530	SPORT	8/8/2003	32	NW	113	41	670	SITKA	3035488
242910	40530	SPORT	8/5/2003	32	NW	113	45	620	SITKA	3035510
254650	40530	SPORT	8/15/2003	33	NW	113	61	713	SITKA	3035600
254709	40369	SPORT	8/20/2003	34	NW	113	31	670	SITKA	3035637
242267	40530	SPORT	9/5/2003	36	NW	113	71	656	SITKA	3035784
254748	40369	SPORT	9/16/2003	38	NW	113	41	675	SITKA	3035792
254747	40369	SPORT	9/16/2003	38	NW	113	41	723	SITKA	3035792
Select Recoveries										
98165	40531	SPORT	10/11/2003	41	NW	113	43		SITKA	3035796
98151	40531	SPORT	8/23/2003	34	NW	113	41		SITKA	3035773
900790	40369	TROLL	9/1/2003	36	NW	113			SITKA	3039984
530511	40530	DRIFT	9/16/2003	38	NW	113	38	610	SITKA	3039969

Appendix A2.–Detection of size-selectivity in sampling and its effects on estimation of abundance and age and size composition.

RESULTS OF HYPOTHESIS TESTS, K-S on lengths of fish

Marked VS Recaptures	Marks VS Captures
Case I:	
Accept H_O	Accept H_O

There is no size-selectivity during marking or recapture, gear types, or locations.

Case II:	
Accept H_O	Reject H_O

There is no size-selectivity during recapture but there is during marking.

Case III:	
Reject H_O	Accept H_O

There is size-selectivity during both marking and recapture, between all gear types, or all locations.

Case IV:	
Reject H_O	Reject H_O

There is size-selectivity during recapture; the status of size-selectivity during marking is unknown.

Case I: Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both marking and recapture events to improve precision of proportions in estimates of composition.

Case II: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from recapture to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data (p. 17).

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Use lengths, ages, and sexes from only recapture to estimate proportions in compositions, and apply formulae to correct for size bias to the data from recapture.

Whenever the results of the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this phenomenon is negligible. Produce a second estimate of abundance by not stratifying the data as recommended above. If the two estimates (stratified and unbiased vs. biased and unstratified) are dissimilar, the bias is meaningful, the stratified estimate should be used, and data on compositions should be analyzed as described above for Cases III or IV. However, if the two estimates of abundance are similar, the bias is negligible in the UNSTRATIFIED estimate, and analysis can proceed as if there were no size-selective sampling during Event 2 (Cases I or II).

Appendix A3.–Capture and recovery data from the Nakwasina River coho salmon mark-recapture study, 2003, by area and date.

Week #	Location	Original Captures	Recaptures	Total Captures	Proportion Tagged
1	2	6		6	0
	3	1		1	0
	Tide Water	3		3	0
2	2	4		4	0
	3	12		12	0
	Tide Water	18		18	0
3	1	1		1	0
	2	45	2	47	0.04
	3	28		28	0
	Tide Water	11		11	0
4	1	1		1	0
	2	31	17	48	0.35
	3	32	3	35	0.09
5	1	2		2	0
	2	30	9	39	0.23
	3	17	9	26	0.35
	Tide Water	4		4	0
6	1	6	1	7	0.14
	2	26	8	34	0.24
	3	28	4	32	0.13
	Tide Water	46		46	0
7	1	57	7	64	0.11
	2	26	4	30	0.13
	3	40	4	44	0.09
8	1	68	24	92	0.26
	2	116	14	130	0.11
	3	20	4	24	0.17
9	1	54	39	93	0.42
	2	47	16	63	0.25
	3	24	10	34	0.29
10	1	28	19	47	0.40
	2	9	4	13	0.31
	3	1		1	0.00
11	1	7	21	28	0.75
	2	18	11	29	0.38
12	1	21	7	28	0.25
	2	4	3	7	0.43
	3	4	4	8	0.50
13	2	5	16	21	0.76
Grand Total		901	260	1,161	0.22

Appendix A4.–Data files used to estimate parameters of the Nakwasina River coho population, 2002 and 2003.

Data File[a]	Description
2003_Adult_CWT_Recoveries.xls	Recovery information from 2003 coded wire tag recoveries in Southeast Alaska.
Nakwasina_River_2003_M-R_and_CWT.xls	Mark, recapture, and coded wire tag recovery information from fish captured in the Nakwasina River in 2003.
2003AdultAWL.xls	Age and length information including summary statistics of adult coho captured in Nakwasina River in 2003.
2002_smolt_AWL_data.xls	2002 smolt raw data including summaries of analyzed data.

[a] Data files were archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.